# MRO – MISSION STATUS

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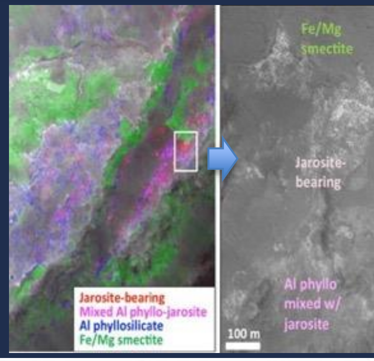
- Launched on August 12, 2005
- Inserted into Mars orbit March 10, 2006
- After aerobraking, achieved Science Orbit in November 2006
  - Low Altitude = 250 km (s. pole) x 320 km
  - Inclination = $92.7^{\circ}$
  - Sun-Sync at ~3:00 am/pm; certified LTST 2-4 pm
- Dual mission now in $4^{th}$ Extended Mission
- Scientific Metrics
  - Over 320 Tb of science data returned
  - > 1200 publications in peer-reviewed journals
  - 8 investigations using 6 instruments & s/c data
    - Atmospheric structure experiment closed out in 2009
  - Covered more than 6 Mars Years (MY 28-34)
- Programmatic Objectives
  - Identification of sites with high potential for future scientific discovery
  - Data for certification of landing site safety
  - Atmospheric monitoring prior to mission EDL
  - Relay & imaging during EDL
  - Relay & monitoring post-EDL

***MEP direction is to keep spacecraft operational for relay and critical event coverage until 2027***

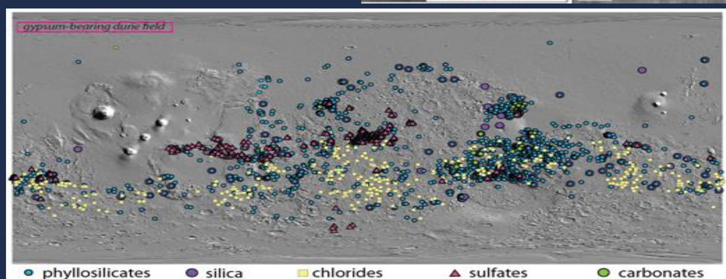
- Fuel reserves > 20 years@10 kg/yr
- Single string telecomm since 2006
- All-stellar capability preserves IMU life
- Building battery capacity ensures long life

# MRO: Four Goals in EM4/EM4E to Study *Mars in Transition*

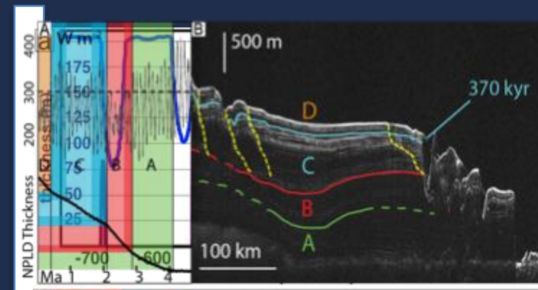
## *1. Ancient Mars: Environmental Transitions and Habitability*

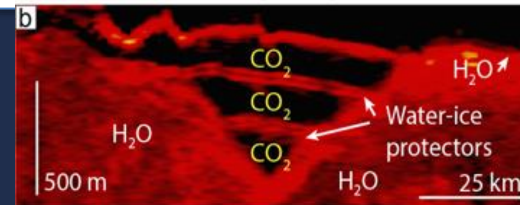



***Aqueous Minerals***




## *2. Amazonian Mars: Ices, Volcanism, and Climate*



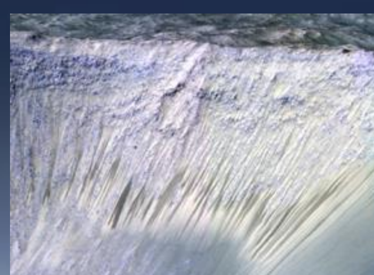



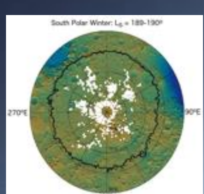

***Ice Ages***

***Volatile Reservoirs***

***Climate Change***

## *3. Modern Mars: Surface Changes and Implications*





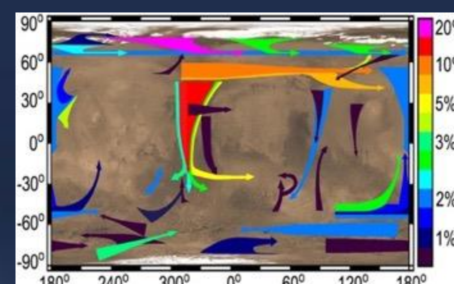
***Volatiles***

***Water Environments?***

***New Impacts***

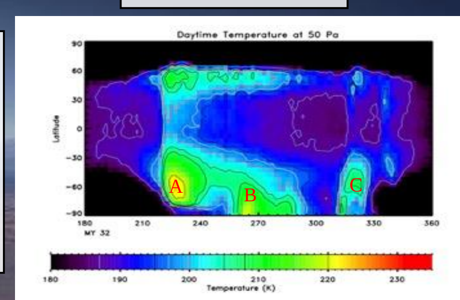

## *4. Modern Mars: Atmospheric and Polar Processes*

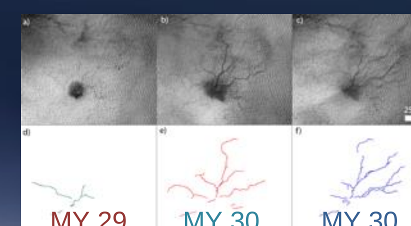
***Storm Tracks***




***Dust Storms***

***Temperatures***

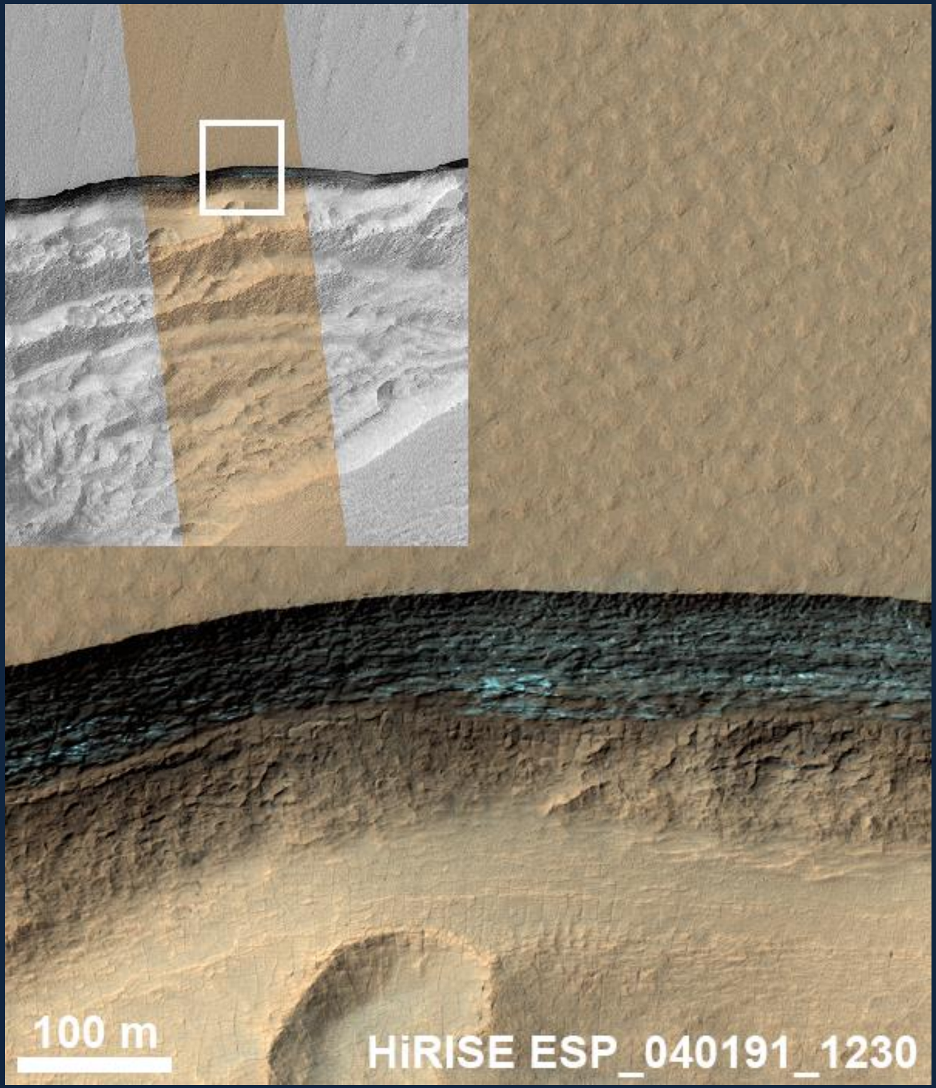



***Polar Changes***

# Exposed Mid-Latitude Ice Sheets on Mars

- Data from HiRISE, CRISM, SHARAD, and THEMIS showing erosional scarps exposing hundred-meter-thick sections of water ice in mid-latitudes of both hemispheres.
- The ice is interpreted as geologically recent remnant deposits, likely laid down at high obliquity, possibly thru multiple climate cycles.
- The ice can be layered or massive, but has low dust content and is covered by only a thin (<1-2 m) layer of dust and regolith.
- Although consistent with SHARAD evidence for thick regional ice sheets elsewhere on Mars, these terrains are relatively lossy in the radar, suggesting a lower fraction of ice.
- These scarps and the associated ice sheets represent both a potential target and a possible resource for exploration, important to NASA strategic goals for Mars exploration.



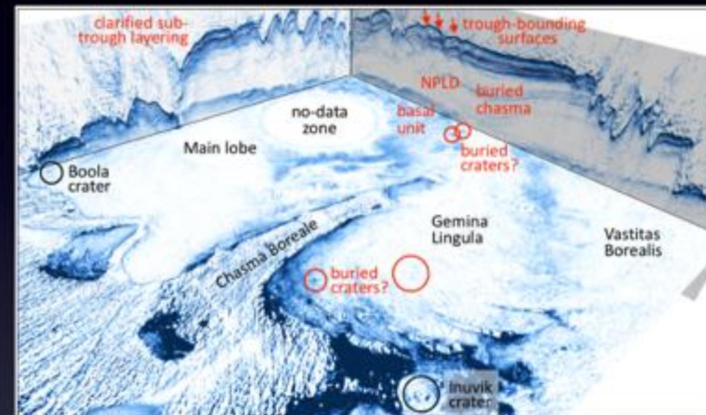

*Dundas, C. M., et al. (2018), Exposed subsurface ice sheets in the Martian mid-latitudes, Science, 359, 199-201*
*Campbell, B. A., & G. Morgan, Geophys. Res. Lettr., 2018.*

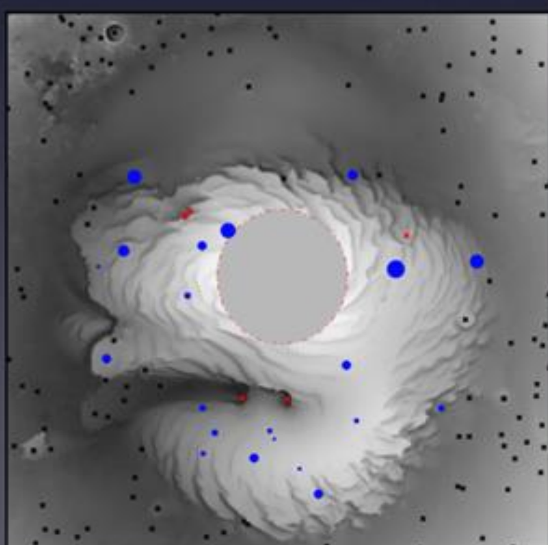
# SHARAD 3-D manuscript in press for *Icarus* special issue on Mars polar science

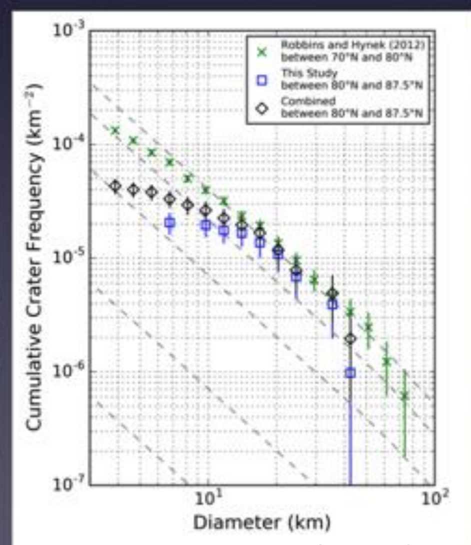
- 3-D radar volumes give clarified views of structures within the Martian polar caps.
- 3-D map of south polar CO2 deposits finds 16,500 km$^3$, 11% larger than prior estimate.
- Apparent impact craters at base of northern cap are consistent with a Hesperian age.
- Radar-derived topography at 86.95–87.45° latitude extends prior laser altimetry data.

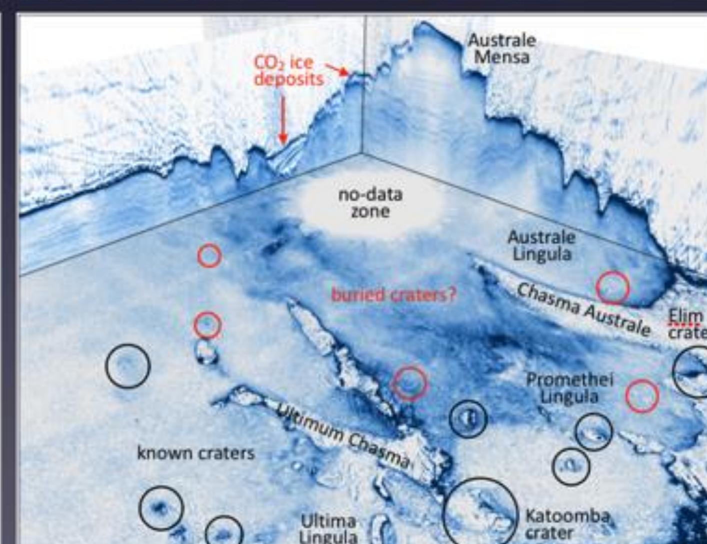
*Icarus* in press, avail. online

Putzig, N.E., Smith, I.B., Perry, M.R., Foss, F.J., II, Campbell, B.A., Phillips, R.J., and Seu, R., 2017. Three-dimensional radar imaging of structures and craters in the Martian polar caps.








Available at http://sharad.psi.edu/3D

# Technical Status of the Spacecraft

***Summary***

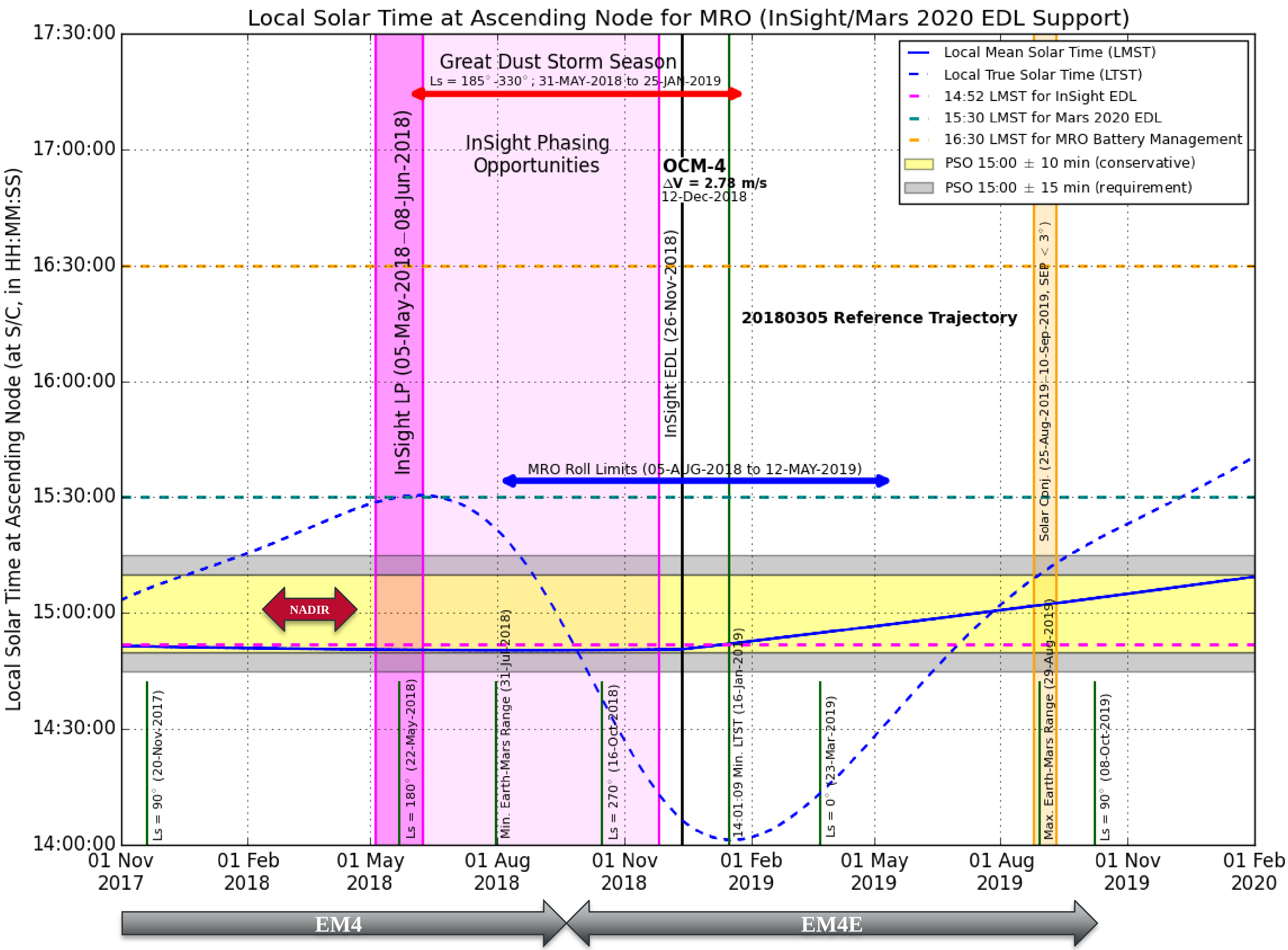
The MRO spacecraft is fully capable of carrying out the proposed EM4E investigations and its programmatic responsibilities for FY19

**Spacecraft aging issues are being mitigated via subsystem management and use of new attitude determination mode; nearly all subsystem redundancy remains**

- Battery life issues - Instituted power management practices to extend battery life: Have reduced spacecraft and payload power loads; Working to increase battery capacity
  - More aggressive charging (than occurred earlier in the mission) has increased battery capacity
  - Battery experts arguing over whether the mission is now "1-battery" safe; however, the only path forward to be sure and to build margin is to continue with the charging
  - Before increasing rate of battery charging, need to recalibrate onboard state of charge (SOC) calculation, so as to not trip fault protection "sanity limits"; can then resume more aggressive charging
  - Moving to later local times (e.g., 4:30 (LMST) remains a back-up option—can decide after M2020 EDL in 2021
- Inertial Measurement Unit (IMU) life limitations - Mitigated through development of All-Stellar attitude determination mode (in operational use with IMU's off since Mar 2018)
  - All-Stellar working well; no prolonged star tracker outages; cannot check for jitter effects on HiRISE until focus is adjusted for new thermal environment (due to battery mitigation during eclipse)
  - IMU is still required for safe mode and special flight activities and sequences, i.e. OTMs, EDL Coverage, etc.
- Payload– CRISM's remaining functional cooler no longer can hold low temperature needed for good SNR; IR observations suspended (including limb scans); continuing to operate on VNIR spectrometer

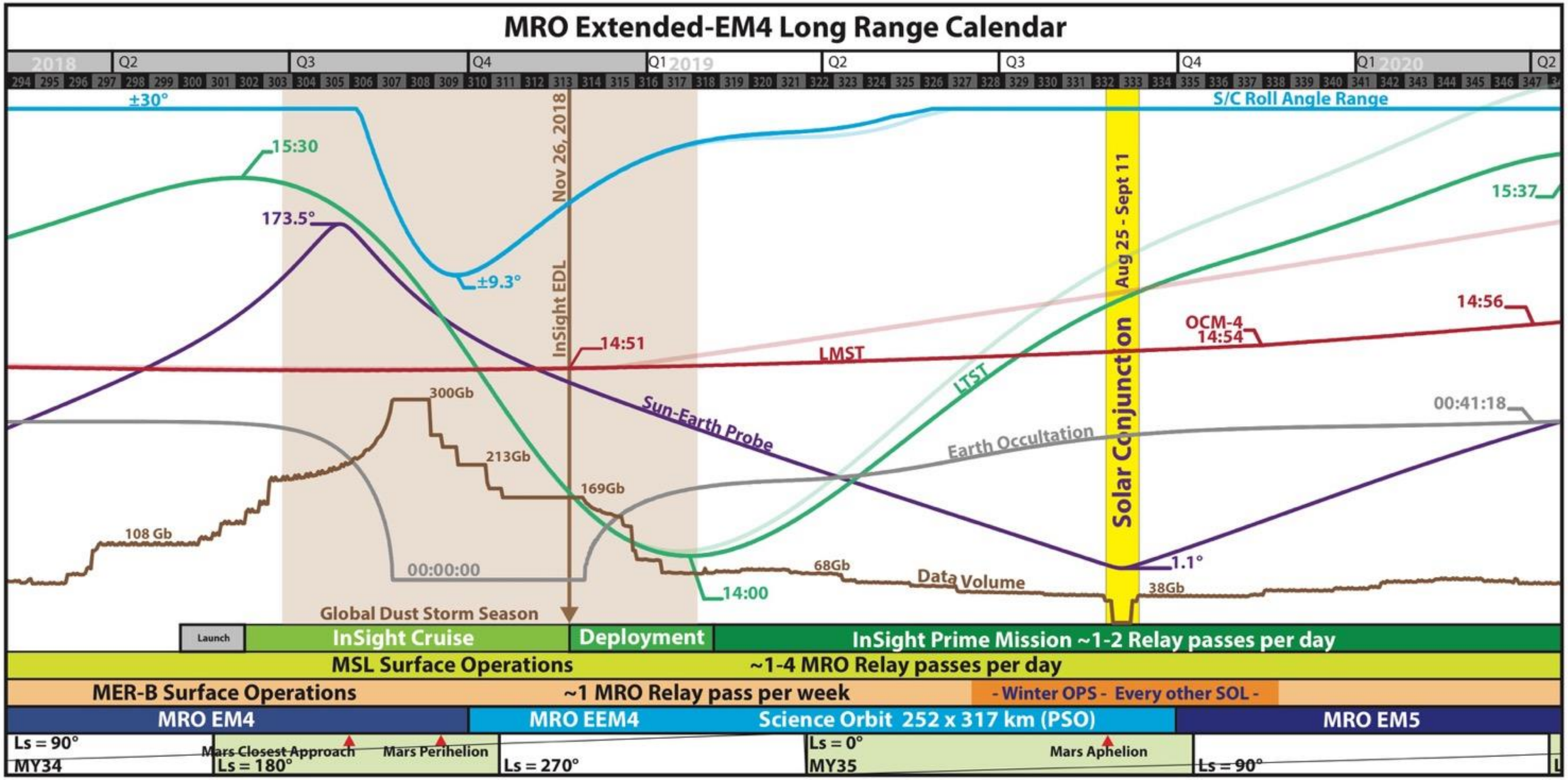
# MRO Mission Plan for the rest of EM4 and for EM4E

## *Operations are within nominal LTST limits*



# Extended Mission 4 Timeline – New

Nov 3, 2017



# Impacts of the FY19 In-Guide Budget

**In-Guide Budget reductions will seriously impact the scientific productivity of MRO**

- **NASA HQ reviewed plans to extend EM4 by one year (FY19) on May 2-3**
  - A report is expected in the next few weeks
  - Expectation: MRO (and all other Mars continuing missions) will be extended for 1 year, with a 3-year Senior Review to follow in the spring of 2019
    - This will require a full proposal and a review by peers, as was done in 2016, but for a 3-year cycle
  - Expectation: There will be little relief to the currently forecasted budget shortfalls for FY19 (impacting most missions); no over-guides were permitted to be presented at the review
- **Impact of In-Guide Budget for FY19:**
  - Spacecraft costs are up, carry-forward was diverted elsewhere in the Mars program, and new funding in FY19 was reduced by ~$1M. The result is ~$2M hit to science
  - Analysis activities will be hard hit, with remaining activities focused on data validation needed for planning and archiving
  - The current planning process is not sustainable under the in-guide budget; starting to look now with POST and SOTs at options to reduce costs
  - Focus will be on acquiring and archiving data, acknowledging that less data may be returned
  - New data products are at risk; may have to go to MDAP or other programs for help
  - Collaboration with other missions will be approached on a best-efforts basis
  - Of the 14 investigations that could technically go forward, 2 will be difficult to address and 8 will face significant issues under the in-guide budget (see next chart)

# Impact of Reduced Budget on Science Investigation Objectives

| Investigation | Technical | Budget | Description | Notes |
|---|---|---|---|---|
| 1 | | | VM Aqueous Deposits | Use CRISM VNIR, prior IR data; S/H/X still address |
| 2 | | | Glass/Impact Heating | No new CRISM IR data |
| 3 | | | Transitional Environments | No CRISM IR; VNIR & HiRISE color address |
| 4 | | | Search for Carbonates | No new CRISM IR data |
| 5 | | | Rover site characterization | Takes a lot of planning |
| 6 | | | Near-Surface Ice | Following up SHARAD & HiRISE discoveries |
| 7 | | | Ice Deposit Structure | Denser coverage for SHARAD 3D mapping algorithm |
| 8 | | | Amazonian Volcanics | No new CRISM IR data; use VNIR; S/H/X |
| 9 | | | RSL and Water today | Compare HiRISE with TGO CASSIS at different LTOD |
| 10 | | | Observe Active Phenomena | Additional MY, but no jitter correction (affects DTMs) |
| 11 | Note #1 | | Changes in Gale Crater | Limited Observations due to relay for MSL & InSight |
| 12 | | | Weather in New MY | Adds S. Summer (great dust storm season); N. spring |
| 13 | Note #2: Global Dust Event? | | Big Dust Storm Event | No CRISM Limb scan; MCS/MARCI ready |
| 14 | | | CO2 Ice/Frost/Snow | MCS campaigns curtailed |
| 15 | | | Profiles from 0 to 150 km; TEC | Fewer joint observations with MAVEN |
| 16 | | | TGO Collaborations | Requires special planning/analysis efforts |
| Green | 13 | 4 | GREEN: Can acquire the data (technical); have budget to do the analysis | |
| Yellow | 1 | 8 | YELLOW: Can address investigation, but there are limitations | |
| Red | - | 2 | **Red: Very difficult to plan and analyze due to budget constraints** | |
| Gray | 2 | 2 | **Gray: Loss of new CRISM IR data makes it difficult to pursue this investigation** | |

**Notes:** 1. This investigation will be more difficult to pursue in EM4E due to relay-related constraints and the arrival of *InSight*
2. Light green indicates dependence on Mars; in particular, whether a global dust event will occur or not in FY19

***The primary limitation to further science progress at a similar level to EM4 is reduced science funding—not technical capabilities of the spacecraft or its science instruments***

# Extended Mission(s) Outline

- November 2017 – Today
- April 2018 - EEM4 review
  - Now– January 15, 2018: Summarize progress on EM4 objectives to date
  - January 15, 2018: High-level decisions on All-stellar/operations strategy
  - January 15-30, 2018: Develop EEM4 objectives (science plan)
  - February 19, 2018: First Integrated Draft Presentation for Review
  - March 19, 2018: Final Presentation Package followed by dry runs
  - March 30, 2018: Review Package ready
- Mar 2018 – Start Regular Use of All-stellar AD
- May 2018 – Finalize Mars 2020 LMST Target (3:30 LMST)
- Nov 2018 - InSight EDL @ 2:52 PM LMST
  - InSight EDL + 14 Days: Initiate Drift to Mars 2020 LMST Target (OCM-4)
- Oct 2019 – April 15 – Prepare 3 year proposal (EM5: FY20-22) for Senior Review
- Oct 2020 - 2022 – Execute EM5
  - Feb 2021 - Mars 2020 EDL Support @ 3:30 PM LMST
  - Mar 2021 - ExoMars RSP - 1st Surface Overflight (Phased)
  - April - ? 2021 - Establish Sun-Synchronize Orbit at 4:30 PM LMST (OCM-6)

# MRO Project Summary

- Given MRO's long-term Programmatic role, Flight System safety and operations remain first priority
  - ❖ MRO will operate within established spacecraft constraints, flight rules, and procedures
  - ❖ Spacecraft longevity issues are being mitigated; nearly all subsystem redundancy remains
- The MRO spacecraft  is fully capable of conducting its dual-purpose mission (science & programmatic support) in FY19 (EM4E)
  - ❖ The mission is highly productive, building on its previous discoveries while providing new findings & improving our understanding of how Mars has changed through time
  - ❖ Its long mission combined with the highest ever spatial resolution orbital sensing capabilities for Mars enable it to characterize change on the planet today in unprecedented ways; the main limitation to scientific progress is funding for science operations and analysis